REMARKS

This response follows an Office Action of January 17, 2002, rejecting claims 1-8. The petition and fee associated with the applicable extension of time is attached herewith.

The Applicant notes the Interview Summary, which is attached to the Office Action. The comments by the Examiner dealing with the substance of the interview reflect the views of the Examiner which are not shared by the Applicant. Thus, where the Examiner states "however during the interview it became clear that...", the Examiner is then setting forth only his contentions. Indeed, as will be set forth herein, the points raised by the Examiner mis-construe individual aspects of the disclosure which in fact would be enabling to one of ordinary skill in this technology.

As a preliminary matter, Applicant points out that the invention here has several different embodiments. In particular, this invention describes several engine variants whose characteristics related to mass and thrust are different. These variants are summarized in the following table:

Type of engine	Inductive nucleochemical in closed loop	Inductive nucleochemical direct injection	Inductive nucleothermal direct injection	Inductive nucleothermal closed loop
Figure number in patent	Fig. 2	Fig. 3	Fig. 4	Fig. 5
Total nuclear power (MW)	3680	3050	3050	3350
Engine thrust (Tons)	258	241	59.6	63.5
Estimated mass for nuclear core (kg)	18400	15000	15000	16700

Specific impulse (s)	561	526	909	967
Ratio thrust/ nuclear core weight	14	16	4	3.8

The nuclear core weight estimation (excluding the Brayton cycle engine and the electric power generation, conditioning, distribution, and the nuclear radiation shields) is based on a specific mass assumption of 0.2 MW/kg. This specific mass is derived from figures obtained at the time of the application for known NERVA reactors, to which additional margins have been added for safety. Another factor increases the conservatism of this assumption: this is a large thrust engine, and the ratio thrust to engine mass improves with the size of the engine.

The thrust to weight ratio defines two categories of engines: The nucleothermal engines with a ratio around 4, and the nucleochemical engines with a ratio around 15. This is normal; an added chemical reaction increases the thrust, but decreases the specific impulse of a nucleothermal engine.

This estimation can be confirmed from:

Nuclear thermal rocket propulsion, Design issues and concepts
By John D.Cinnamon Department of Aerospace Engineering, University of Texas at Austin,
Spring 1992

This document (attached) makes a synthesis of several possible nuclear thermal rocket designs, based on the NERVA technology. Their design is quite different from the Applicant's, but for the nuclear heating part only the mass should be comparable.

The table 5.3 shows details on the design of such engines. Even though the operating parameters are somewhat different from our assumptions, it is interesting to look at the

composite engine in the middle column, whose technology readiness level (bottom of the table) is rated 4 to 6 (component validated in laboratory, up to subsystem demonstrated in relevant environment)

For a nuclear reactor power of 1613 MW, the mass breakdown is:

Reactor	5853	kg
Non-nuclear	2559	kg
Total engine	8412	kg i.e. 0.19 MW/kg
Internal radiation shield	1517	kg
External radiation shield	4674	kg

It should be noted that, in the Patent Application, the ratio 0.2 does not include the mass of the protective shields (see p.17 lines 16-19).

It should be also noted that in the "non-nuclear" mass turbopumps are accounted which Applicant includes in the Brayton cycle mass, added to the nuclear core mass (more conservatism)

Applicant's mass estimation for the part within the state of the art correlates well with previous data, while staying on the conservative side.

For the NERVA-1 engine, the reactor power is 1520MW, whereas the mass breakdown is

Reactor	5476	kg
Non-Reactor	2559	kg
Total Engine	8035	kg i.e. also 0.19 MW/kg

As a consequence, the figure of 0.2 MW/kg which is considered as conservative with a particle bed reactor was already known in prior art .

The Examiner's position on enablement of the heat engine 18, which employs a nuclear core 19 as its heat source can then be explained away. Clearly, the disclosure relies only on the use of a nuclear core as a technique of providing heat, but that certainly does not mean that the invention employs steam as the heated medium. It is believed beyond debate that it has been known for a very long time to operate a heat engine to generate heat and here, the manner in which heat is generated is not material to the operation of the heat engine. The Examiner, however, appears to believe that a heat generating nuclear reactor needs to be tested in a simulated space or rocket environment, that is somehow flight qualified hardware. That is an unnecessary qualification.

Rather, the Applicant's citation of Borowski on page 3, lines 4-17 was simply to point out that in the case of NERVA, the system employed a nuclear thermal propulsion device as a historic milestone. As pointed out on page 3 of the specification, it was known based on that technology that heat generated by a nuclear reactor can be directly transferred into a gas. The nuclear core there produced 300 tons of thrust with a specific impulse (Isp) of 800 seconds. Reference is made to page 3, lines 10-17. The technology goes back nearly 40 years to use a nuclear reactor to heat a gas in a flight qualified environment. Certainly, as set forth in the literature, this produces a thrust in a specific impulse with values commensured with the examples employed here.

The Examiner's statement of rejection on page 2, seemingly one which would imply that the heat engine here is one which is used to produce steam is not on point. It is clear that the Applicant's invention does not use steam, but the reference in the previous remarks was only to demonstrate that the use of nuclear reactors as heat sources is notoriously well known. Thus, the Examiner has incorrectly extrapolated the comments of the Applicant, which were intended to convey only that the use of nuclear energy as a heat source was well known. That source had been quite flight and qualified would demonstrate to the artisan to the use of heat engine 18 employing a nuclear core 19 as set forth here.

To the extent that there has been confusion, the Applicant trusts that the Examiner now clearly understands what the reference in the specification to Borowski was meant to convey.

Specifically, this invention implements the heating of gas in conditions that are comparable with those set forth in the prior art, that is NERVA. However, the use of the heated gas in this invention is materially different.

As the Examiner can appreciate, the gas that is heated by a nuclear reactor is used as the hot source of a BRAYTON machine. However, for the cold source of such a BRAYTON in the context of rocket engines, cryogenic stored liquid is employed.

The Examiner can then appreciate that this invention makes use of a cryogenic cold source, which exists at about 60°K and a high temperature hot source at about 2000°K, which provides for a very high efficiency. The Examiner should also note that the temperature of 2000°K is specifically chosen because it is compatible with the existing state of the art in turbine technology when used in a helium environment. Reference is made to page 14, lines 6-29.

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The Examiner also contends that it is not enabling how to make a BRAYTON cycle with a pressure ratio of 82.2 and a factor of 0.2. With respect to the first point, the Examiner should note formula (V) in which temperatures T1 and T3 are given as examples. In this invention, the compressor 43 produces a compression ratio of 82.2.

The Examiner should note that by way of comparison, the Space Shuttle uses turbopump compressors, which deliver hydrogen at a pressure of 426 bars. This is far more severe in terms of demand requirements than that employed by the present invention.

The Examiner's criticism of the fact 0.2 on page 17, at line 15 is for the purpose of evaluating the weight of the nuclear core, which he can appreciate is not a part of the BRAYTON cycle device. The Applicant has explained how the factor is obtained. It relates to 0.2 MW/kg. This ratio is readily obtainable by using a particle bed reactor and it was also obtainable in the prior art NERVA system as shown above. Stated differently, this example was used by the inventor to demonstrate that at the time the invention was made, this was the best technology employed. It is respectfully submitted that the Examiner's criticism is, however, misplaced because enablement of a nuclear core here is simply one to produce heat in an amount commensured with those readily obtained 40 years ago such as in the NERVA system. Thus, it is believed that the issue of enablement has been explained and the Examiner's apparent misdirection taken from prior comments has been rectified. The rejection in paragraph 2 should thus be removed.

The Applicant has cancelled claim 1 and has replaced it with a new claim 14. This removes rejection in paragraph 3.

With respect to the objection to the specification in paragraph 4, the Examiner should note that the example of 60 kHz is simply the production of that alternating current using a rotor operating at 500 Hz, for which the use of a frequency converter is suggested in an alternative embodiment. The value of 60 kHz is nothing more than an example for use of a particular nozzle.

Turning next to the prior art rejections, new claim 14 is a combination of claims 1 and 2 and further drafted to remove the rejection in paragraph 6. The rejection in paragraph 8 is removed because Applicant deletes claim 3.

Dailey, however, remains germane given the rejection in paragraph 7. It is believed that the claims are distinguishable over that reference. In Dailey, gases are chemically heated and begin the expansion process prior to reaching the induction coil, which generates a varying electric and magnetic field. This field is used to ionize and magnetically accelerate the reaction products. Dailey unambiguously defines such in column 2, lines 13-20.

In Dailey, the magnetic field is generated by an induction coil and as the Examiner can appreciate, it is a time-varying magnetic field. In contrast, the varying electric field occurs due to circulation of electrons and plasma, which are accelerated by a Lorentz force. This has the disadvantage of operating in a direction, which is opposite that of the thrust direction during a portion of each cycle. The electrons circulate and thus do not continuously produce thrust in the same direction.

Dailey then recognizes the necessity to provide a drive circuit for the purpose of supplying current in a coil to maximize forward thrust and minimize the reverse thrust. The

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reverse thrust is simply a dampened sinusoidal isolation having a short discharge period at a high

current level and a long charging period at a low current level.

Dailey thus relies on a combined chemical-electro magnetic propulsion system having

two significant attributes. First, gases are chemically heated to form high temperature ionizable

reaction products. Secondly, additional thrust is provided by accelerating the gas using magnetic

acceleration forces (Lorentz).

With that understanding, the Examiner's contention that Dailey inherently heats the

injected gases using the current and a loop 16 is incorrect. More properly, the reference

unambiguously chemically heats the gases. That is, Dailey makes clear that the heating affect is

obtained by chemical reaction. Only by magnetic acceleration is additional thrust obtained. The

Examiner's contention is further rebutted by Dailey by reference to column 5, lines 12-14.

Dailey specifically references that a symmetrical current wave form would produce no net thrust.

Thus, even if there were some inherent heating of the gases by the induction coil, as the

Examiner opines, it would be expected that there would be some contribution to the net thrust.

Dailey, however, clearly recognizes that the induction coil produces no-net thrust. The artisan

would quickly then recognize that there is no heating of the ejected gases by the induction coil of

Dailey.

Additionally, Dailey clearly does not employ the thermal affects of induction, even if

present in his system. Had the contrary conclusion been the case, and Dailey contained an

unambiguous recognition of inductive heating affects, then the system of Dailey would have

certainly not have been designed in a manner of the reference. As the Examiner can appreciate,

the signal generated by Dailey has a disadvantage of limiting the power, which is transmitted because the discharge period in which thrust is obtained must be significantly longer than the charging period. Reference is made to column 5, lines 14-25 of Dailey.

The Applicant in drafting new claim 14, as a combination of claims 1 and 2, claims specifically that the gas is heated by induction and additional thrust is provided by the expansion of the induction heated gas in a divergent section of the nozzle, which is positioned downstream of the coil. Clearly, Dailey does not perceive or in anyway suggest that subject matter.

The Applicant also respectfully traverses the Examiner's comments concerning the inherency of heating using alternating current in relying on Curtis. Curtis clearly defines and relates to a plasma accelerated apparatus and specifically one which is directed to an ionized gas. The Examiner is incorrect in his assertion that Curtis has any application to a non-ionized gas. Reference is made to column 6, lines 24-30. There, Dailey specifies and defines the term "plasma" as "a volume of gas in which an appreciable percentage of the atoms are ionized..." The Examiner is incorrect that this reference has any pertinence to the heating of a non-ionized gas.

Additionally, like Dailey, Curtis employs Lorentz forces to generate thrust. In order for this to occur, the plasma must be brought to a high temperature to be ionized so that the Lorentz force is generated. The Examiner's reliance on column 3, lines 40-42 is irrelevant to the issues. That passage deals with water cooled coils to carry away heat generated in this gas. Clearly, Curtis wants to dissipate the heat in the gas and not use any heating effects for purposes of generating thrust.
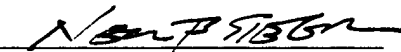
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In summary then, the Applicant respectfully request that the Examiner reconsider the

propriety of the rejection here. Each ground of rejection has been met and explained.

Should the Examiner have any questions, he is requested to contact the undersigned

attorney of record at the local exchange listed below.

The USPTO is directed and authorized to charge all required fees, except for the Issue

Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any

overpayments to said Deposit Account.

Respectfully submitted,

SUGHRUE MION, PLLC
2100 Pennsylvania Avenue, N.W.
Washington, D.C. 20037-3213
Telephone: (202) 293-7060
Facsimile: (202) 293-7860

Neil B. Siegel
Registration No. 25,200

Date: June 17, 2002

APPENDIX
VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

The specification is changed as follows:

A speed of rotation of 30,000 revolutions per minute (rpm), which is representative of the normal speed of rotation of a turbopump, makes it possible to produce electricity ~~directly~~ at a frequency having the same order of magnitude as that required without requiring the presence of a complicated frequency converter. In industrial applications, it is known that frequency converters present a large amount of mass and also suffer from the drawback of poor energy efficiency for an induction heating system.

IN THE CLAIMS:

Claims 1, 2 and 3 are canceled.

The claims are amended as follows:

4. (Amended) A device according to claim ~~1~~14, wherein at least one of said propellant fluids feeds at least a first heat exchanger for cooling the electricity generator.

5. (Amended) A device according to claim ~~1~~14, wherein the injection chamber has a first inlet for a first propellant fluid, and a second inlet for a second propellant fluid which enters into the injection chamber and reacts chemically to produce heat.

Claim 14 is added as new claim.